ThermoAnalytics

TOTAL THERMAL SOLUTIONS

RadTherm 10.1 & Future

March 2011

Agenda

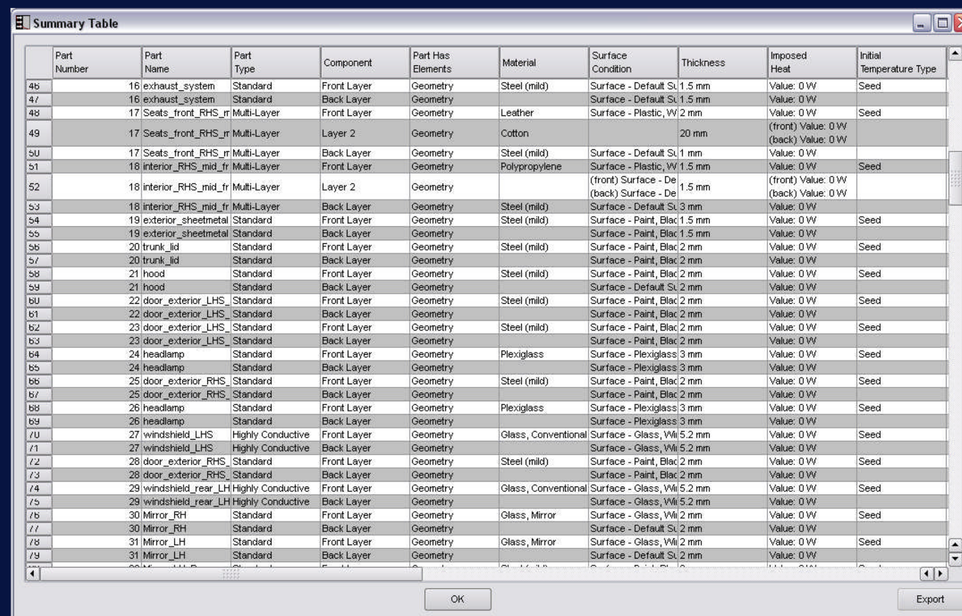
- RadTherm 10.1 New Features
- RadTherm 10.1 Automation Features
  - Editable Summary Table
  - Thermal Link Wizard
- Vision
  - Advanced Thermal Solver
  - Human Thermal Comfort
  - Battery Modeling
  - Optimization

RadTherm v10.1

- Application
  - Editable Summary Table
  - BC Import & Export
  - Thermal Link Wizard
    - Generation & Visualization
  - Abaqus Export
  - Archive with Right Click
- Thermal
  - Battery Model
    - Cell & Pack Plug-in
  - Solar Apparent Area
    - Adjustable Recalculation
  - Patch View Factors
- Post Processing
  - Graphics Window
    - Set Center of Rotation
  - Smooth Animation Export
- Human Thermal
  - Physiology
    - PhysioGen
    - ASHRAE 2 Node Model
  - Analysis
    - Transient Restart Options
    - Comfort Visualization

Editable Summary Table

- Editable Summary Table
  - Edit BC's from spreadsheet view
  - Edit multiple parts simultaneously
  - Linked to Graphics Window
  - Advanced filtering
  - Sort on multiple columns
  - Only show columns with data
  - Import/Export



Summary Table

	Part Number	Part Name	Part Type	Component	Part Has Elements	Material	Surface Condition	Thickness	Imposed Heat	Initial Temperature Type
46	16	exhaust_system	Standard	Front Layer	Geometry	Steel (mild)	Surface - Default Su	1.5 mm	Value: 0 W	Seed
47	16	exhaust_system	Standard	Back Layer	Geometry		Surface - Default Su	1.5 mm	Value: 0 W	
48	17	Seats_front_RHS_r	Multi-Layer	Front Layer	Geometry	Leather	Surface - Plastic, W	2 mm	Value: 0 W	Seed
49	17	Seats_front_RHS_r	Multi-Layer	Layer 2	Geometry	Cotton		20 mm	(front) Value: 0 W (back) Value: 0 W	
50	17	Seats_front_RHS_r	Multi-Layer	Back Layer	Geometry	Steel (mild)	Surface - Default Su	1 mm	Value: 0 W	
51	18	interior_RHS_mid_fr	Multi-Layer	Front Layer	Geometry	Polypropylene	Surface - Plastic, W	1.5 mm	Value: 0 W	Seed
52	18	interior_RHS_mid_fr	Multi-Layer	Layer 2	Geometry		(front) Surface - De (back) Surface - De	1.5 mm	(front) Value: 0 W (back) Value: 0 W	
53	18	interior_RHS_mid_fr	Multi-Layer	Back Layer	Geometry	Steel (mild)	Surface - Default Su	3 mm	Value: 0 W	
54	19	exterior_sheetmetal	Standard	Front Layer	Geometry	Steel (mild)	Surface - Paint, Blac	1.5 mm	Value: 0 W	Seed
55	19	exterior_sheetmetal	Standard	Back Layer	Geometry		Surface - Paint, Blac	1.5 mm	Value: 0 W	
56	20	trunk_lid	Standard	Front Layer	Geometry	Steel (mild)	Surface - Paint, Blac	2 mm	Value: 0 W	Seed
57	20	trunk_lid	Standard	Back Layer	Geometry		Surface - Paint, Blac	2 mm	Value: 0 W	
58	21	hood	Standard	Front Layer	Geometry	Steel (mild)	Surface - Paint, Blac	2 mm	Value: 0 W	Seed
59	21	hood	Standard	Back Layer	Geometry		Surface - Default Su	2 mm	Value: 0 W	
60	22	door_exterior_LHS_	Standard	Front Layer	Geometry	Steel (mild)	Surface - Paint, Blac	2 mm	Value: 0 W	Seed
61	22	door_exterior_LHS_	Standard	Back Layer	Geometry		Surface - Paint, Blac	2 mm	Value: 0 W	
62	23	door_exterior_LHS_	Standard	Front Layer	Geometry	Steel (mild)	Surface - Paint, Blac	2 mm	Value: 0 W	Seed
63	23	door_exterior_LHS_	Standard	Back Layer	Geometry		Surface - Paint, Blac	2 mm	Value: 0 W	
64	24	headlamp	Standard	Front Layer	Geometry	Plexiglass	Surface - Plexiglass	3 mm	Value: 0 W	Seed
65	24	headlamp	Standard	Back Layer	Geometry		Surface - Plexiglass	3 mm	Value: 0 W	
66	25	door_exterior_RHS_	Standard	Front Layer	Geometry	Steel (mild)	Surface - Paint, Blac	2 mm	Value: 0 W	Seed
67	25	door_exterior_RHS_	Standard	Back Layer	Geometry		Surface - Paint, Blac	2 mm	Value: 0 W	
68	26	headlamp	Standard	Front Layer	Geometry	Plexiglass	Surface - Plexiglass	3 mm	Value: 0 W	Seed
69	26	headlamp	Standard	Back Layer	Geometry		Surface - Plexiglass	3 mm	Value: 0 W	
70	27	windshield_LHS	Highly Conductive	Front Layer	Geometry	Glass, Conventional	Surface - Glass, Wi	5.2 mm	Value: 0 W	Seed
71	27	windshield_LHS	Highly Conductive	Back Layer	Geometry		Surface - Glass, Wi	5.2 mm	Value: 0 W	
72	28	door_exterior_RHS_	Standard	Front Layer	Geometry	Steel (mild)	Surface - Paint, Blac	2 mm	Value: 0 W	Seed
73	28	door_exterior_RHS_	Standard	Back Layer	Geometry		Surface - Paint, Blac	2 mm	Value: 0 W	
74	29	windshield_rear_LH	Highly Conductive	Front Layer	Geometry	Glass, Conventional	Surface - Glass, Wi	5.2 mm	Value: 0 W	Seed
75	29	windshield_rear_LH	Highly Conductive	Back Layer	Geometry		Surface - Glass, Wi	5.2 mm	Value: 0 W	
76	30	Mirror_RH	Standard	Front Layer	Geometry	Glass, Mirror	Surface - Glass, Wi	2 mm	Value: 0 W	Seed
77	30	Mirror_RH	Standard	Back Layer	Geometry		Surface - Default Su	2 mm	Value: 0 W	
78	31	Mirror_LH	Standard	Front Layer	Geometry	Glass, Mirror	Surface - Glass, Wi	2 mm	Value: 0 W	Seed
79	31	Mirror_LH	Standard	Back Layer	Geometry		Surface - Default Su	2 mm	Value: 0 W	

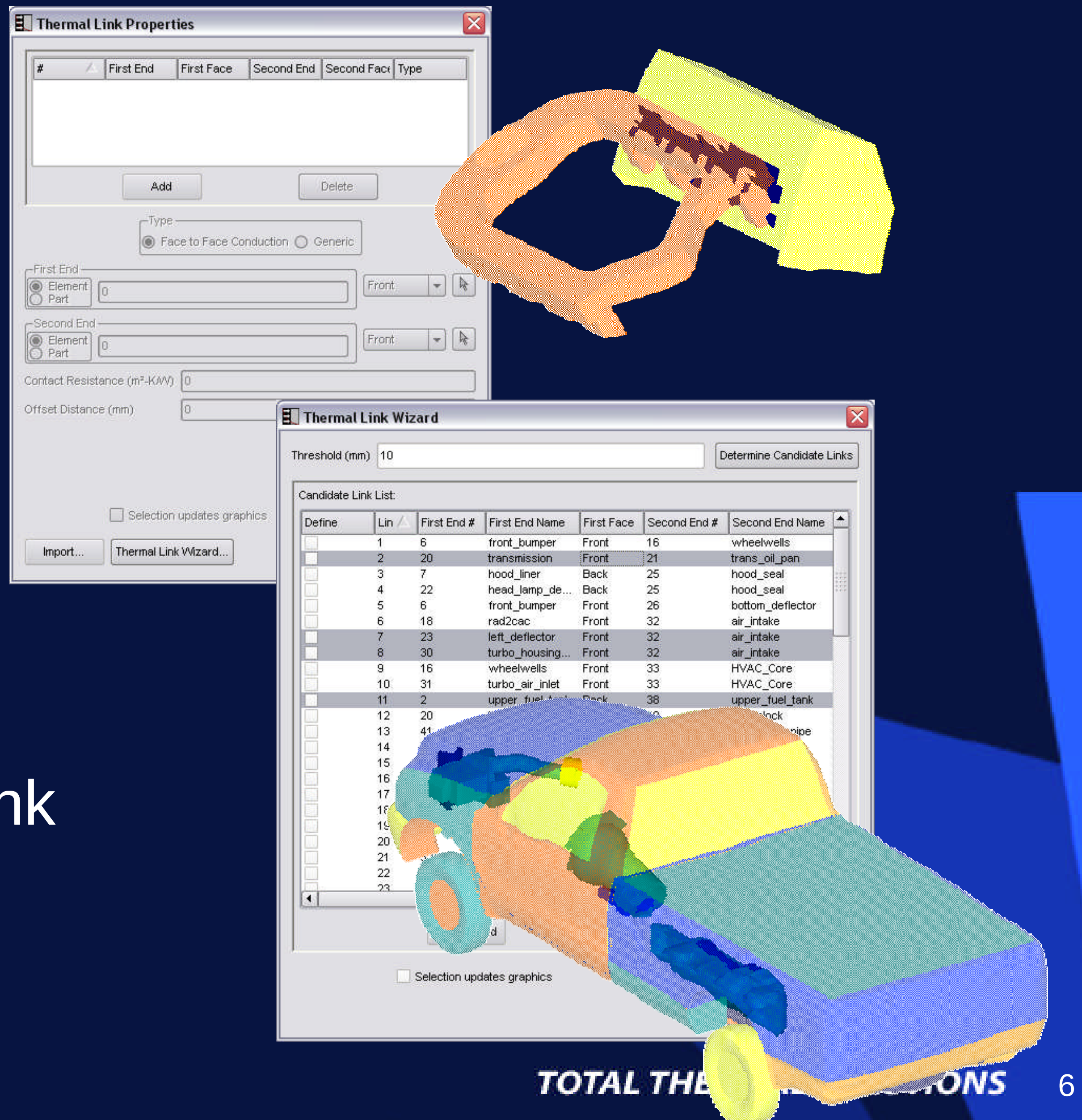
OK Export

Boundary Conditions I/O

- Boundary Conditions Import & Export
  - Reuse boundary conditions for similar cases or scenarios
  - Part Name or Part ID based replacement
  - Change Summary & Log
  - Edit in Excel and re-import

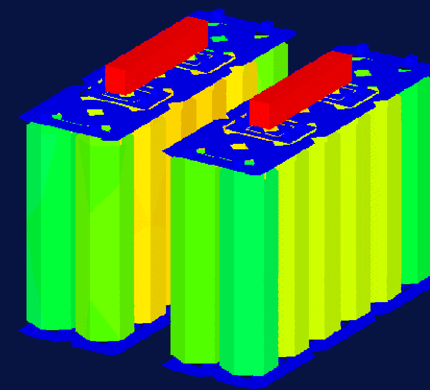
Thermal Link Wizard

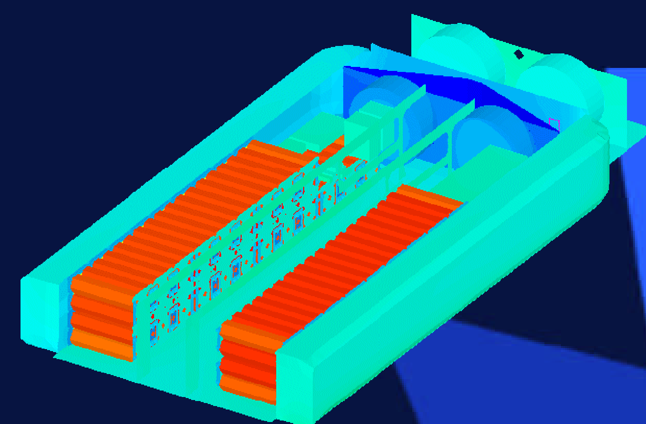
- Instantly identify all Thermal Link Candidates in a model
  - Limit to Visible Parts
  - View Multiple Candidates
  - Isolate Candidates and view Thermal Link



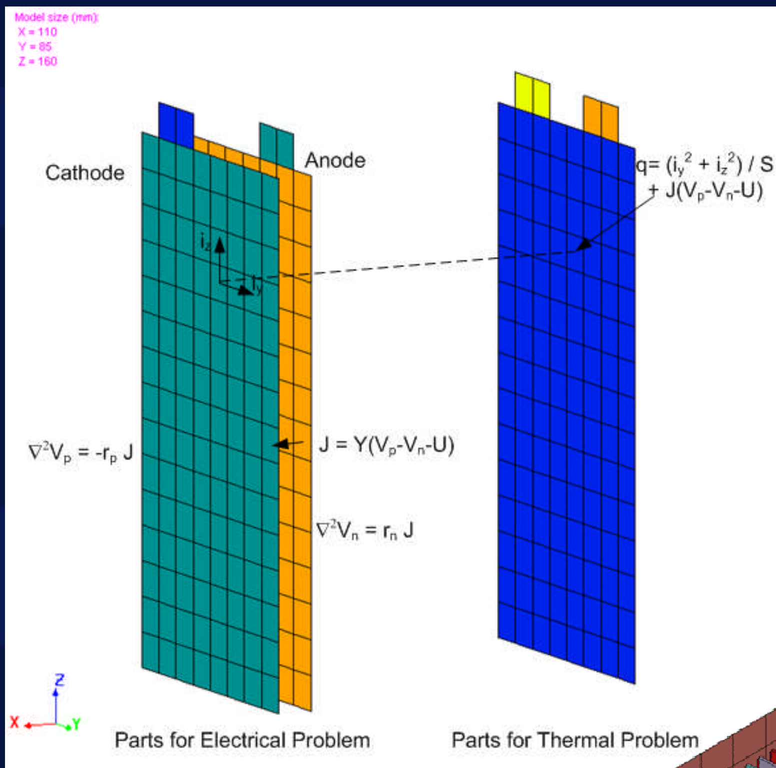
Battery Thermal Model

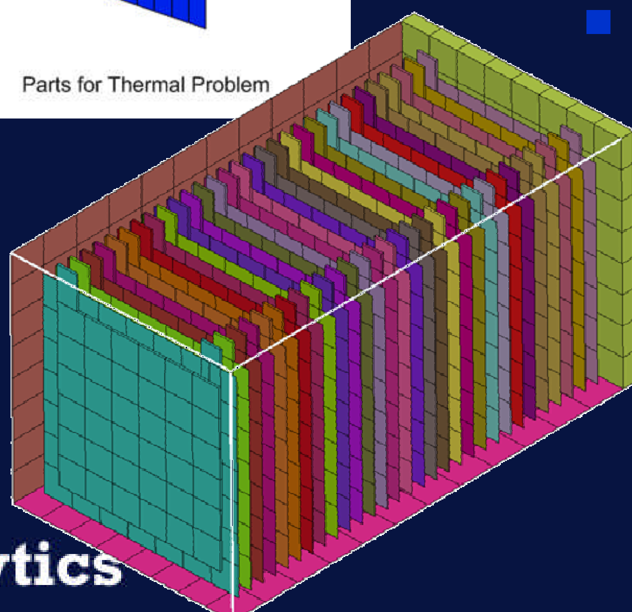
- Battery Plug-in (Ajou Model)
  - Currently available as beta version
- Partnering with OEMs & Battery Suppliers on validation
  - voltage & temperature predictions
- Transient Scenarios
  - Drive Cycle
  - Hot Soak & Cold Start
  - Load Balancing
  - Cooling System Faults
- Integration of NREL equivalent circuit model for battery packs
  - Large packs, Cylindrical batteries





Ajou Battery Model

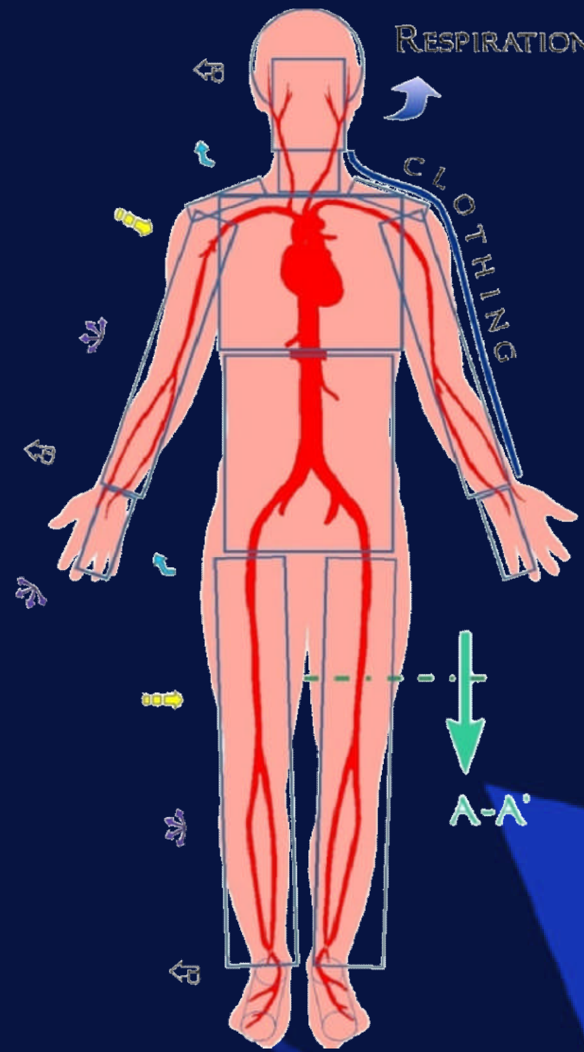




- **Electrical problem**
  - 2D array of 1D models of current density through electrodes
  - 2D description of voltage distribution on collector plates
- **Thermal problem**
  - 2D description of temperature distribution on electrodes
- **Two problems coupled via joule heating**
  - Calculated in electrical problem
  - Imposed in thermal problem

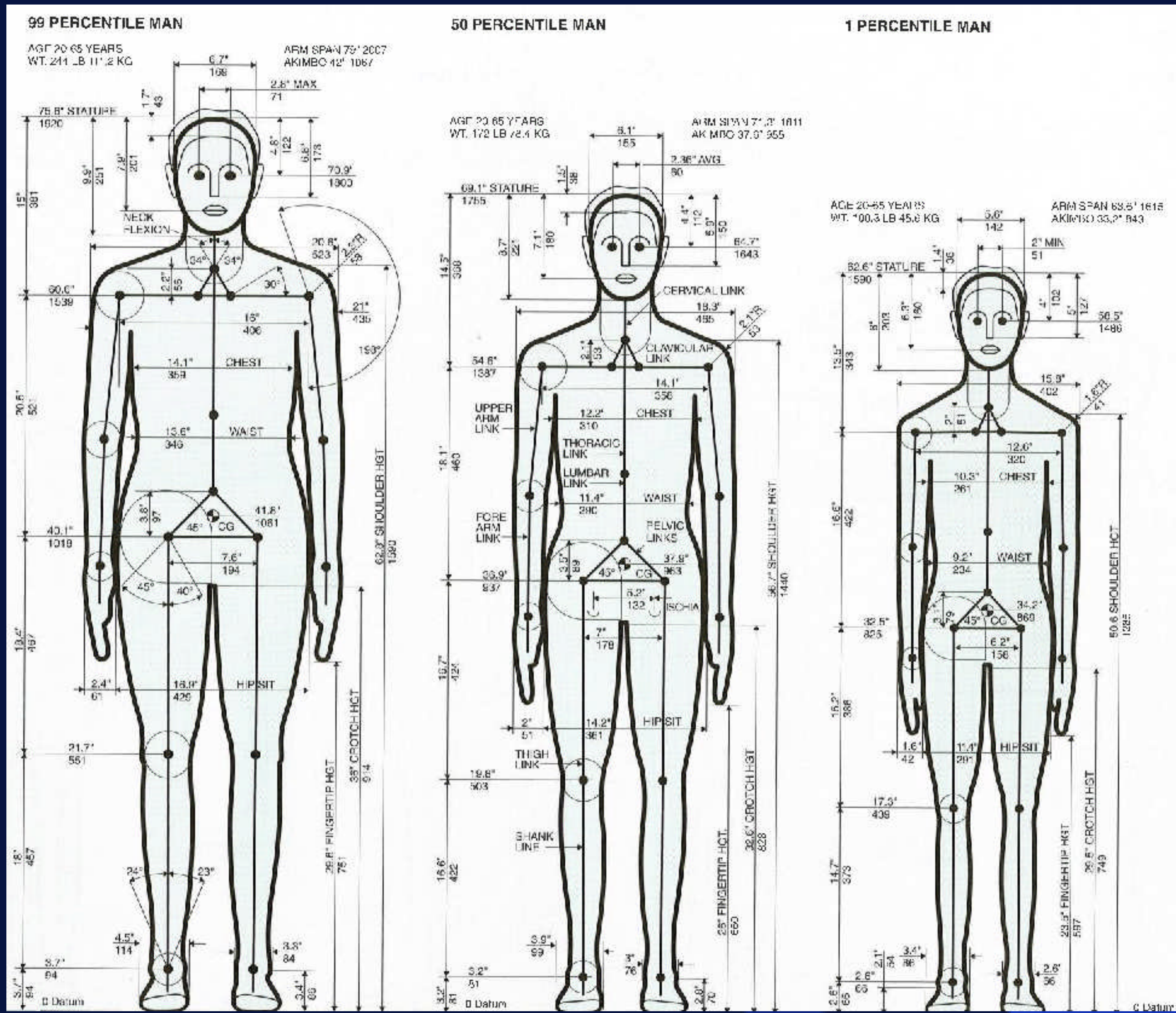
Standard Physiology

- Fiala's "Standard Man"
  - 50th Percentile Male
- Physiological Parameters
  - Segment Lengths
  - Tissue Radii
  - Thermal Properties
    - Basal Metabolic Heat Rates
    - Blood Perfusion Rates
    - Conductivity
    - Density
    - Specific Heat
  - Sensitivity Coefficients
  - Distribution Coefficients
    - Sweating, Shivering etc.
- User Defined Segments



Human Physiologies

- Detailed body build from established anthropometric data
- 1st to 99th percentile
  - Independent Weight
  - Independent Height
- Adjustments
  - Segment Lengths
  - Segment Diameter
    - Fat, Muscle & Bone



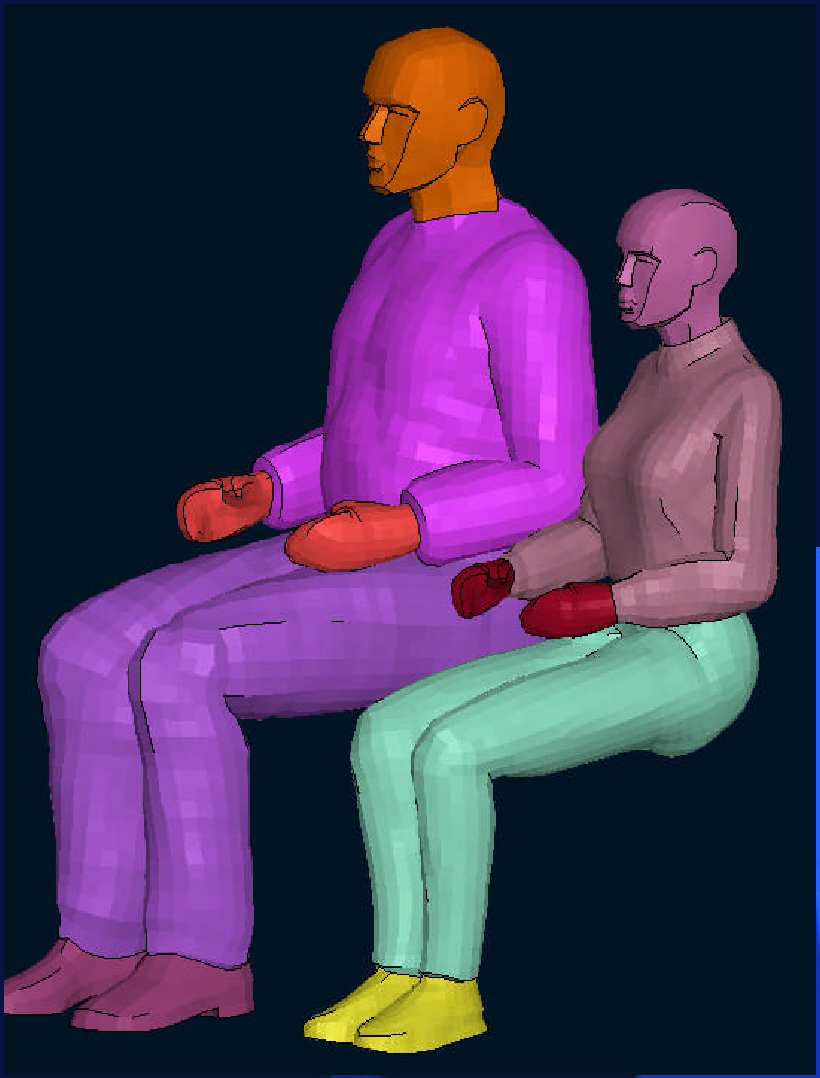
Physiogen

- Multiple humans with unique
  - Physiology & Size
  - Poses & Mesh resolution
  - Boundary conditions
- Build Physiology
  - Input: Simple Parameters

    Body Percentile, Ethnic, Gender

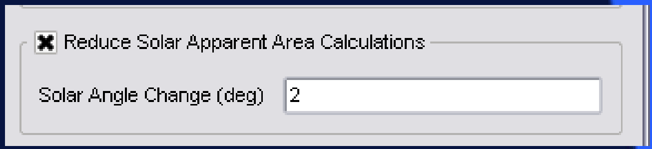
    ↓
  - Output: Physiological Parameters

    Blood volume, surface area, thermal conductivity, basal metabolic rate, etc.



Other RadTherm 10.1 Features

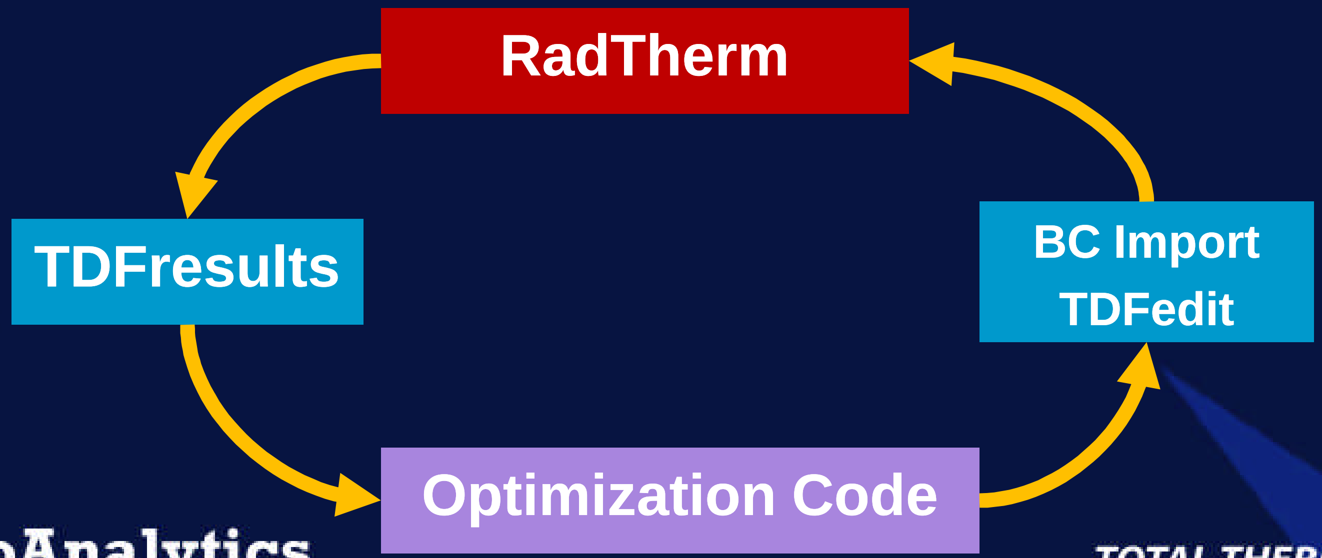
- Abaqus Export
  - Export geometry & temperatures as .INP input file for thermal stress analysis
- Archive with Right Click
  - Windows Explorer
- Solar Apparent Area Calculation
  - Adjustable Recalculation



- Patch View Factor
  - Reduce VF calculation time for large models

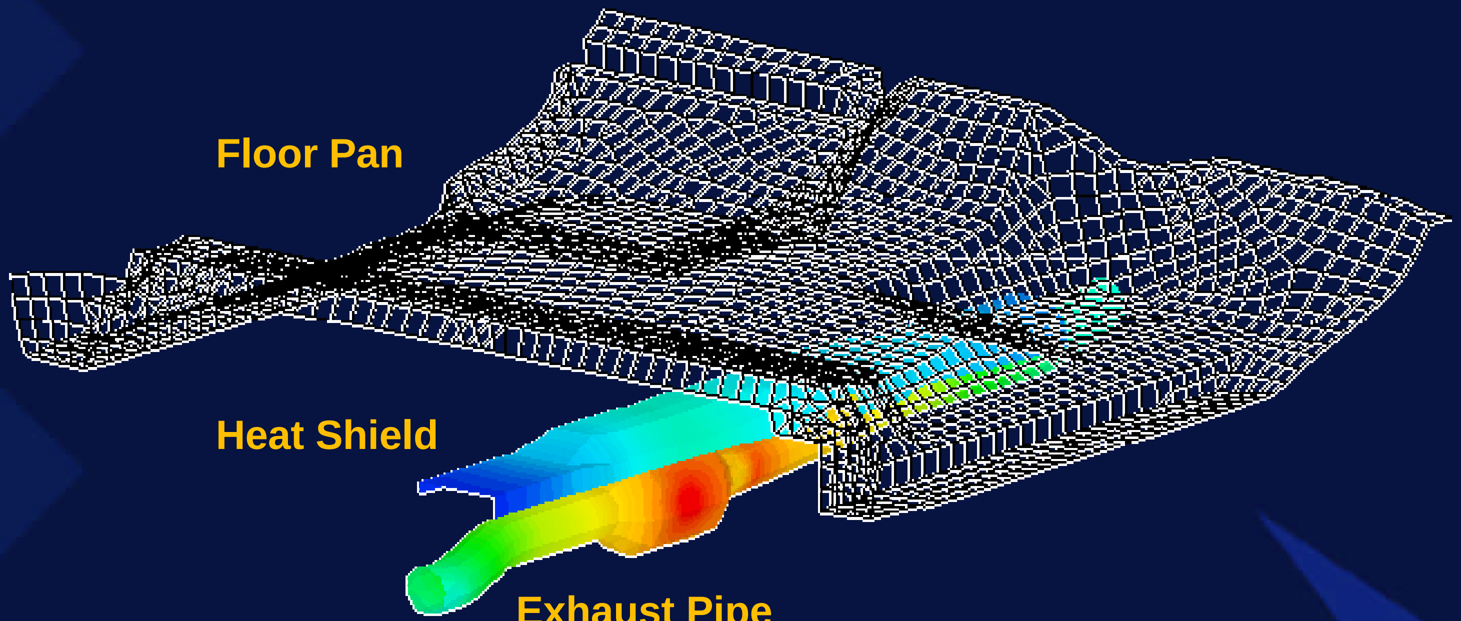
Optimization

- Optimization Codes
  - modeFRONTIER
  - iSIGHT
- Integration tools:
  - TDFedit: modify RadTherm model parameters using ASCII file
  - BC Table: modify model BC’s using CSV file
  - TDFresults: writes avg, min, max, etc part temperatures

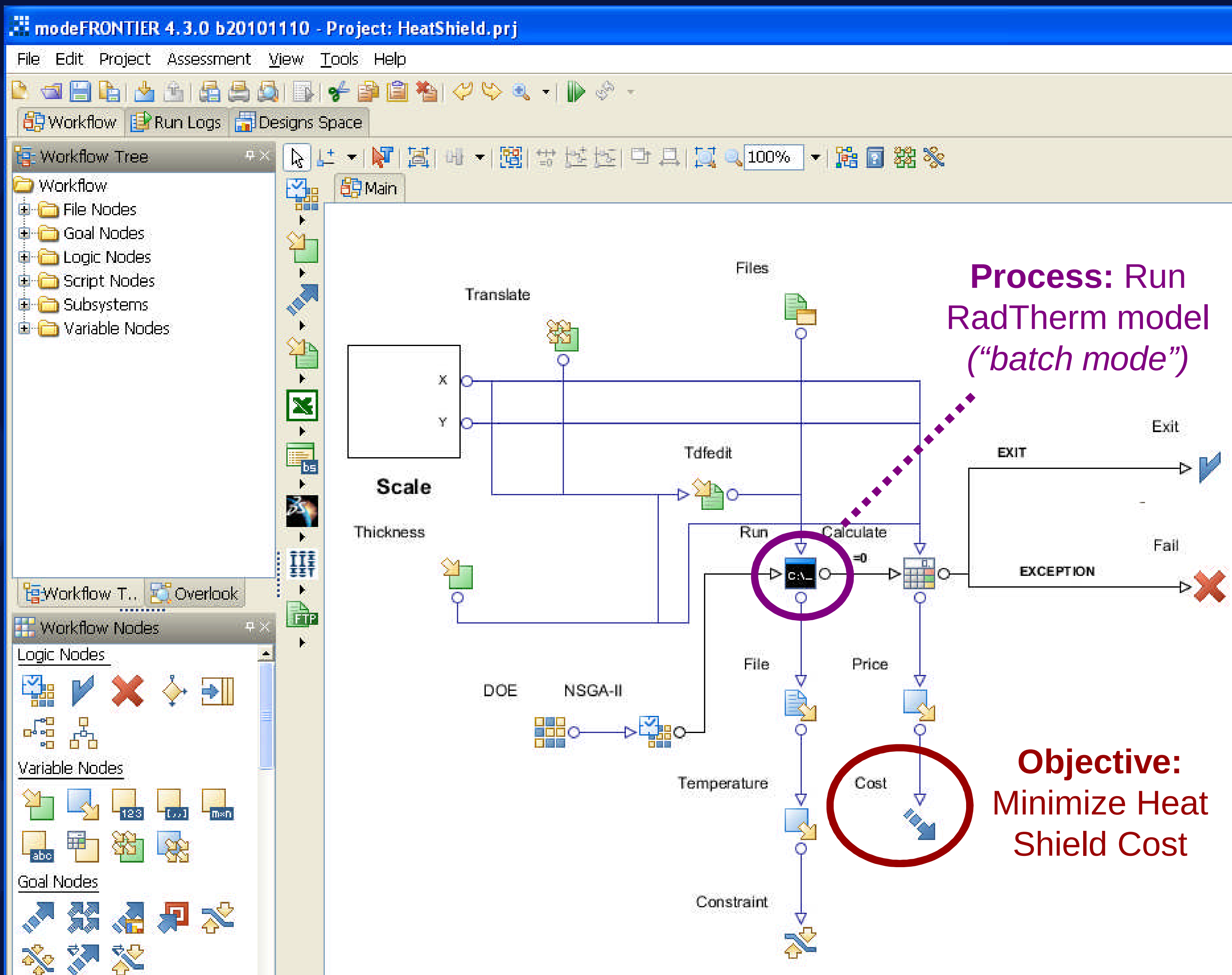


Heat Shield Optimization

- **Process: Heat Shield & Floor Pan Optimization**
  - Vary heat shield thickness
  - Vary floor pan insulation thickness
  - Simulate design to ensure temperature requirements have been met
  - Compute combined cost of heat shield & floor pan
- **Objective**: Minimize material cost while achieving safe floor pan temperatures



ModeFRONTIER Workflow



Complex Heat Shield Results

- Heat shield and floor pan insulation materials differ
- Thicknesses were optimized to meet temperature requirements while minimizing material costs
- Optimization could also include material selection, surface roughness/polish, etc.